

BELLCOMM, INC.

1100 SEVENTEENTH STREET, N.W. WASHINGTON, D.C. 20036

COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE- Planetary Launch Trajectory and
Optimization Computer Program
Trak-2

TM-68-1013-1

DATE- April 2, 1968

FILING CASE NO(S)- 720

AUTHOR(S)- J. J. Schoch

FILING SUBJECT(S)- Trajectory Optimization
(ASSIGNED BY AUTHOR(S)-

ABSTRACT

The "Trajectory and Targeting Computer Program Trak-1" described in a previous technical memorandum has been gradually improved. The additional features of the program have been incorporated in a new edition called "Planetary Launch Trajectory and Optimization Computer Program Trak-2". The purpose of this memorandum is to bring the users up to date on all these new features.

The great flexibility of the previous version of this program regarding the targeting has been expanded into the optimization feature. Additional improvements are the capabilities of selecting a specified planetary atmosphere model (for Earth, Mars or Venus), introducing an arbitrary thrust or pitch table, and evaluating the engine out performance of a multi-engine stage.

One of the examples used in the previous memorandum is expanded by the use of the optimization feature.

(NASA-CR-95448) PLANETARY LAUNCH TRAJECTORY
AND OPTIMIZATION COMPUTER PROGRAM TRAK-2
(Bellcomm, Inc.) 36 p

N79-71563

FF No.
6

100-45440
(NASA CR OR TMX OR AD NUMBER)

(CATEGORY)

00/12

Unclassified
11143



BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Planetary Launch Trajectory and
Optimization Computer Program
Trak-2 - Case 720

DATE: April 2, 1968
FROM: J. J. Schoch

TM-68-1013-1

TECHNICAL MEMORANDUM

INTRODUCTION

Launch vehicle mission analysis requires the determination of a trajectory such that certain mission objectives be satisfied by appropriately varying some input parameters. If the number of input parameters is equal to the number of mission objectives, then the problem is determined. In a previous memorandum(1)*, a "Trajectory and Targeting Computer Program" called Trak-1 was described. Trak-1 is capable of handling a case having a number of input parameters (called "Targeting Parameters") equal to the number of mission objectives (called "Terminal Conditions"). Should the number of targeting or input parameters exceed the number of terminal conditions (or mission objectives), then more than one solution exists. In this case, it is desired to determine that set of input parameters that will optimize some variable; for instance maximize payload.

Such an optimizing feature has been added to the "Trajectory and Targeting Computer Program" Trak-1 and the resulting Computer Program designated Trak-2; "Planetary Launch Trajectory and Optimization Computer Program". The new program can handle any case handled by the older version Trak-1.

Further improvements have been incorporated. They permit the use of various models of planetary atmospheres, greater ease in modifying the input by the use of the "Namelist" feature available in Fortran V, and the possibility of prescribing variable pitch, thrust, and lift.

This memorandum is written as a complement to the original Trajectory and Targeting Computer Program and some familiarity with it is assumed of the reader.

*Numbers in parenthesis apply to references.

1. DESCRIPTION OF OPTIMIZATION PROBLEM

The problem is best described by using the first example given in Section 7.2 of (1). This example treats a three stage vehicle which is launched into a 100 NM circular orbit. The 100 NM circular orbit defines the terminal conditions, sometimes referred to as mission objectives. They are in this case, altitude, velocity, and flight path angle in earth orbit. These terminal conditions may be considered as dependent variables and are satisfied by determining the proper value of the independent variables; in this case the guidance parameters A and B and the burning time of the third stage. These parameters were defined as targeting parameters in (1).

Some other independent variables may be considered such as kick-angle, propellant loading, or interstage coasting times.

In case the number of independent variables equals the number of terminal conditions then the problems reduces to a targeting problem as given in (1) and the independent variables can be uniquely defined. In case the number of independent variables is larger than the number of terminal conditions, the problem is undetermined. It becomes determined if one variable, in this case for instance third stage burning time, is optimized. The problem may then be described in the following manner:

Determine the independent variables in such a manner as to:

- 1) satisfy the terminal conditions, and
- 2) optimize the third stage burning time.

Various approaches to this problem may be found in the literature.

1.1 Description of Method Used for Optimization

The approach applied here is as follows. Let there be m terminal conditions or dependent variables and n independent variables, where $n > m$. The first m independent variables are selected and used as targeting parameters while the remaining $n-m$ independent variables are used for optimizing some objective. Returning now to the first example of (1) it will be assumed that one additional independent variable is available: the kick-angle.

Since there are three terminal conditions, three of the independent parameters are selected as targeting parameters. They may be the three parameters used in (1). This choice is completely arbitrary and had three other parameters been selected, the final results would be identical. The remaining parameter, kick-angle, will be the optimizing parameter. The problem may then be defined as follows: determine the kick-angle in such a manner as to minimize third stage burning time and adjust at the same time, for each value of kick-angle, the targeting parameters in such a manner as to satisfy the terminal conditions.

The numerical values of the targeting parameters are different for each kick-angle, and consequently targeting has to be repeated for each different value of kick-angle. The problem is, therefore, divided into two parts: an external one in which the kick-angle is appropriately changed in order to get a minimum burning time and an internal one in which for each value of kick-angle, the targeting parameters are adjusted so as to satisfy the terminal conditions. The internal one is solved by the existing targeting scheme using the secant method while the external one is solved by using the secant hypersphere method described in (2).

The interrelation between targeting and optimization may be better understood from Figures 1 and 2. Figure 1 attempts to illustrate the process schematically while Figure 2 is a block diagram of the procedure. Let it be assumed that the process has reached a point where for a certain value of kick-angle the targeting parameters A, B, and burning time have been determined in such a manner as to satisfy the given terminal conditions. The optimization scheme determines now a new value of kick-angle which is expected to bring the burning time closer to its minimum. This new kick-angle is then used in calculating a new trajectory using the values of the targeting parameters determined for the previous value of kick-angle. Since these targeting parameters will not satisfy the given terminal conditions they will have to be re-determined in such a manner as to make the error in terminal conditions arbitrarily small. Only then is it possible to check how the new value of burning time compares with the old one and whether it is close enough to its as yet unknown minimum. Should it not be close enough to the minimum, then the secant hypersphere method will provide a new value for the kick-angle and a new iteration similar to the one described is executed. This process is continued until the decrease in burning time between two successive iterations becomes negligible.

The concept of optimizing parameter and optimized parameter will be introduced next. Those independent parameters such as kick-angle in the given example that are changed in order to optimize another parameter will be referred to as optimizing parameters. The parameter whose optimum is sought will on the other

hand, be referred to as optimized parameter. Consequently, all parameters such as payload, kick-angle, burning time, and propellant loadings, which have been listed as targeting parameters in (1) may be also selected as optimizing parameters.

It should be furthermore noted that the optimized parameter has to be used as a targeting parameter in that particular problem. The example just mentioned will help to explain this. In this example the targeting parameters were the two guidance parameters A and B and the burning time of the third stage. The terminal conditions were altitude, flight path angle, and velocity. Consequently, for every kick-angle a third stage burning time, together with the parameters A and B, is determined such that the terminal conditions are satisfied. This results in a one by one relationship between kick-angle and any of the targeting parameters for instance burning time. This is the curve that is optimized. It can only be optimized if the optimized parameter, third stage burning time, changes for every kick-angle. It can only do this if it is a targeting parameter.

2.0 DESCRIPTION OF THE NEW INPUT CAPABILITIES

The new input capabilities provide more flexibility; they do not, except for a few instances described below, change the manner in which a case is entered.

2.1 Planetary Constants and Atmospheres

This is a new feature which must be used. The fourth card (or fourth line on the input form) is changed. It contains now in addition to the number of sections on column 10 the following entries:

Planet Identifier (Column 20)

Planets are numbered sequentially starting with Mercury. For Earth launches a numeral three has to be entered.

The entry of the planet identifier causes the program to select the appropriate values for planetary radius, gravitational constant, and rotational speed; however, the user may, at his option, enter his own value of planet radius and gravitational constant as he has done with Trak-1. The planetary constants used by the program are listed on Table 1.

In this connection a little digression with respect to vehicle weight is required. The mass of the vehicle is, of course, invariant and if it were given for defining the vehicle stages no difficulty would be experienced. It is, however, customary to

define not the mass but the weight of the vehicle's components and this weight is based upon Earth g's. In order to use the equations of motion as defined in Subsection 2.1 of (1) it is necessary to multiply the quantity \bar{w}_o occurring in equation (1) and (3) by the factor g_o/g^* . w_o expresses what the weight would be on Earth at altitude zero; $g_o = \frac{\mu}{R^2}$ is the acceleration of gravity at zero planetary altitude and g^* is the acceleration of gravity at altitude zero on Earth. Therefore, on Earth the quantity $w_o(g_o/g^*) = w_o$ and on any other planet the weight is corrected accordingly. The program uses the value $g^* = 32.1740486 \text{ ft/sec}^2$.

Atmosphere Identifier (Column 30)

The program contains the following atmospheres:

- | | | |
|-------|---|-----------------------------------|
| Earth | 1 | U. S. Standard Atmosphere, 1962 |
| | 2 | Patrick Air Force Base Atmosphere |
| Mars | 1 | JPL - Mars Model Atmosphere VM3 |
| | 2 | JPL - Mars Model Atmosphere VM8 |
| Venus | 1 | Upper Density Model (See Ref. 4) |
| | 2 | Mean Density Model |
| | 3 | Lower Density Model |

The atmosphere identifier has to be entered.

2.2 Optimization Features

Details on the optimization are entered on the fifth card or the fifth line of the input form. Entries on that line are as follows:

Number of Targeting Parameters: (Column 10)

Number of Segments Within a Section: (Column 20)

Information Relative to Desired Printout: (Column 30)

For a: Program prints as follows:

- | | | |
|-----------|-------------------|--|
| Blank | Normal | For targeting runs the last line of each iteration then a complete printout of the last iteration. |
| Print-out | | |
| 1 | Extended Printout | Prints every line of every iteration. |

2	Condensed Printout (for opti- mization runs only)	Prints last line of every iteration of the optimiza- tion process.
---	---	--

Usually the blank entry is used. If trouble is experienced extended printout may be desirable; when everything runs smoothly the condensed printout is recommended.

Identifier of Optimized Parameter (Column 40)

As stated in sub-section 1.1, the optimized parameter has to be a targeting parameter. In the entry above it is defined as such by entering its targeting parameter identifier.

Flag for Punching Cards (Column 50)

This entry is identical to the one given in (1).

Optimizing Parameters

The optimizing parameters are entered in the same way as are the targeting parameters. Their identifiers are numbered consecutively starting with the number of targeting parameters plus one. So for instance, if there are n targeting parameters and two optimizing parameters, the identifiers of the optimizing parameters will be n+1 and n+2.

The remaining information for optimizing is entered on cards 7, 8, and 9 or on the corresponding lines on the input form. Note that these cards are read only if an optimization is called for by defining an optimized parameter identifier.

Card 7 contains the lower limit of the optimized parameter followed by the lower limits of all the optimizing parameters. Each entry occupies 10 spaces.

Card 8 contains the corresponding higher limits.

Card 9 has two entries. A "1" (one) in column 1 is used to indicate a minimization problem; any other entry or blank signifies a maximization problem. The accuracy requested for the optimization is indicated next on columns 2 to 16. As a general rule, an entry of 0.05 will be satisfactory.

2.3 Possibility of Changing Previously Defined Input Parameters

The feature to be described was introduced mainly for the use of remote terminals. It provides the possibility of changing any of the previously entered parameters. This is done by using the Namelist features of Fortran V as described in (3).

The list of variable names to be used in connection with Namelist is given in Appendix A. The set of changed parameters should be enclosed between two cards: a "\$Input" card and a "\$END" card. If no input has to be changed, a card with "\$Input" and one with "\$END" are still required. If it is desired to run more than one case, then a card with a "1" (one) on column 5 should be inserted between the different sets of parameters, i.e., between the "\$END" card of one set, and the "\$Input" card of the following set. All cases except the first have to be given with "Namelist". The first case should always be given in the conventional way.

2.4 Thrust and Pitch Tables

These tables are entered by means of the Namelist input. The following variables are entered for thrust:

NUMT = x

where x stands for the number of elements of the thrust tables (up to 90)

followed by

TVI = a_1, a_2, \dots, a_n

where the array a_i stands for the values of thrust,

XISP = b_1, b_2, \dots, b_n

where the array b_i stands for the values of ISP, and

TIMI = c_1, c_2, \dots, c_n

where the array c_i stands for the values of time.

In order for the program to use the thrust tables, the stage has to be considered as a solid rocket stage (see (1)).

The pitch table is entered in similar fashion. The following variables are entered:

NUMP = y

where y is the number of elements of the pitch table (up to 90)

followed by:

PTIME = d_1, d_2, \dots, d_n where the array d_i stands for the values of time, and

PITCH = e_1, e_2, \dots, e_n where the array e_i stands for the values of pitch.

The program will use a pitch table when a "4" is used as guidance scheme. It will provide the desired pitch versus time relationship.

All entries in the pitch and thrust tables are given as real numbers except for NUMP and NUMT which are given as fixed point numbers.

2.5 Engine Out Capability

This feature permits evaluating the engine out capability of a vehicle. The following input parameters are entered:

- 1) Engine out time (EOT). This is the time (in seconds) starting from the beginning of the trajectory segment at which the engine fails.
- 2) Thrust fraction (EOTF). This is a number, smaller than 1, indicating that fraction of normal thrust available under the engine out conditions.
- 3) Propellant weight at which thrust decay calculation begins (WD).
- 4) Time interval for thrust decay (TD).

The thrust decay calculation is based upon a thrust decay table which is given as a fixed input. All engine out parameters are entered by means of namelist.

3.0 SAMPLE TRAJECTORY

The first sample trajectory given in Section 7.2 of (1) will be expanded to include optimization. Instead of prescribing the kick-angle it will be determined in such a manner as to minimize the burning time of the last stage.

Except for the changes described in the preceding sections and the optimizing parameters the input is essentially the same as in (1). For comparison purposes a printout of the input cards is shown on Table 2.

Tables 3 to 16 are a reproduction of the actual computer run. Table 3 shows a reprint of the input cards followed by a complete list of all the variables and their values. This list extends through Tables 4 and 5. Table 6 shows the general description of the vehicle followed by the vehicle weight history which extends into Table 7. A list of the targeting and optimizing parameters follows, then the terminal conditions. The actual calculations start with Table 8. Only the last line of each iteration is shown. It takes 4 iterations to target for the initially given kick-angle (top of Table 9). The same calculations are repeated for a little smaller value of kick-angle (remaining of Table 9 and top of Table 10) and a little larger value (remaining of Table 10) and top of Table 11). This gives 3 values of the function "3rd stage burning time vs. kick-angle". From these three values the secant hypersphere optimization method determines a potentially better one (remaining of Table 11 and top of Table 12) and in one additional approximation the accuracy criterion for the optimization is satisfied. On Table 13 and 14 the updated constants and the vehicle weight history are repeated. They are followed on Table 15 by a detailed printout of the trajectory. Table 16 shows the optimization history. This shows how the optimization was started with a kick-angle of -0.001396 radians which provided a burning time of 183.51 seconds. Decreasing the kick-angle to -.001354 radians provides a burning time of 184.80 seconds while an increase in kick-angle to -0.001438 radians reduced the burning time to 182.75 seconds. At this point the optimization scheme selected a kick-angle of -0.001476 radians which gave a burning time of 182.5266 seconds and after another attempt with a kick-angle of -0.001477 radians this value was maintained, indicating that the optimum has been reached.

4.0 PROGRAM DETAILS FOR USAGE

The present version of this program Trak-2, may be obtained from the Computer Library or the author. It consists of the following sub-routines.

DECAY	LKUP	CONIC	KEY	TRAK
WTADD	INTERP	FINDV	LOSS	THRUST
T	PLAT	TIMELI	FUNC	CNVRT
WOLFE	INTP	ANOMAL	LCOM2	PRESS
GAUSS	POLY	DENSTY	IND	STAGE
INPR	DRAG5	LCOM1	OFUNC	
ERVECT	SST	LCOM3	PAC	
FROMX	DWITCH	LCOM4	OPTIMA	
UPDATE	WRITE	POINTS	TOX	

Running time for the sample problem is less than 2 minutes.

ACKNOWLEDGMENT

The cooperation of Mrs. P. D. Chessick who made all the program changes leading to the new Trak-2 version is herewith gratefully acknowledged.

1013-JJS-sjh

J J Schoch
J. J. Schoch

Attachments

BELLCOMM, INC.

REFERENCES

1. Schoch, J. J., "Trajectory and Targeting Computer Program", TM-1021-2, March 1, 1966.
2. Long, P. F., and Schoch, J. J., "Secant Hypersphere Approximation of "Gradient Methods" for n-Dimensional Function Optimization", TM-66-1021-5, September 30, 1966.
3. Univac Data Processing Division, Fortran V, Programmers Reference Manual #U.P.-4060.
4. Smith, Robert E., "Space Environment Criteria Guidelines for Use in Space Vehicle Development (1965 Revision)", NASA TMX-53273, Aero Astrodynamics Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama.

BELLCOMM, INC.

APPENDIX A

List of variable names for Namelist input.

Variables are given in the order in which they are entered on the input form.

General Constants

**(1)	GMIU: Gravitational constant of planet (ft ³ /sec ²)	(1)
	RADIUS: Planetary radius (ft)	(1)
*	KAZ: Targeting sequence number for azimuth	(-)
	AZ: Launch azimuth	(Deg)
	ALATI: Launch latitude	(Deg)
	ALAMDI: Launch longitude	(Deg)
*	KP: Targeting sequence number for payload	(-)
	PAYLD: Payload	(lbs)
*	NTITLE: An entry of 1 provides titles	(-)
	VZERØ: Initial condition for velocity	(ft/sec)
	GAZERØ: Initial condition for flight path angle	(Deg)
	ALZERØ: Initial condition for altitude	(ft)
	RAZERØ: Initial condition for range	(N.Miles)
	TIZERØ: Initial condition for time	(Sec)
*	KK: Targeting sequence number for kick-angle	(-)
	AKICK: Kick-angle	(Deg)

(1) If this variable is not entered, the program uses the value given in Table 1.

*,** All parameters are entered as real variables. Note, however, that parameters indicated by an asterisk (*) are to be entered as fixed point numbers and those designated by two asterisks (**) are to be entered as floating point variables.

	DELT _K :	Kicking time interval	(Sec)
*	PLANET:	Planet identifier	(-)
*	ATM _S :	Atmosphere identifier	(-)
	CL:	Lift coefficient	(-)
	NUMP:	Number of elements in pitch table	(-)
	NUMT:	Number of elements in thrust table	(-)

Section Parameters

The following parameters have one subscript indicating the section.

*	NTARG:	Number of targeting parameters in that section	(-)
*	M:	Number of segments in that section	(-)
*	NTT:	Printing option	(-)
*	NPNCH:	Punching option	(-)
*	NØPTI:	Indicates which targeting parameters is optimized	(-)
	EPS:	Accuracy requirement for targeting	(2)

Optimizing Parameters

	EX:	Lower limit of optimized variable	(-)
	G:	Higher limit of optimized variable	(-)
*	MX:	Indicates minimization problem if "1"	(-)
	EP:	Accuracy criterion	(-)
	C:	Lower value of optimizing parameters	(3)
	D:	Higher value of optimizing parameters	(3)

(2) The subscript here refers to the targeting parameter sequence number.

(3) These parameters are subscripted. The subscript refers to the optimizing parameter (n+1, n+2, etc.).

Segment Parameters

The following parameters refer to segments. They carry two subscripts, the first referring to the segment and the second referring to the section.

WDW:	Stage burnout weight	(lbs)
WDOT:	Stage burning rate	(lbs/sec)
*	KPR: Stage propellant targeting sequence number	(-)
	PROP: Stage propellant	(lbs)
*	KTH: Targeting sequence number for thrust	(-)
	TH: Thrust	(lbs)
	PL: Stage payload	(lbs)
*	KT: Targeting sequence number for stage time	(-)
	TIMOP: Stage time	(sec)
	DELT: Integration time interval	(sec)
*	NG: Guidance scheme parameter	(-)
*	NSW: If "l" transforms to inertial coordinate systems at end of segment	(-)
*	NFLAG: Use for propellant sharing	(-)
*	NY: Stopping criterion for conic section	(-)
*	JP: Printout frequency	(-)
	PNOZ: Stage nozzle pressure	(lbs/ft ²)
	ANOZ: Stage nozzle area	(ft ²)
*	NC: Drag curve indicator	(-)
	AFRO: Frontal area of vehicle	(ft ²)
	FISP: Specific Impulse	(sec)

	DELW:	Weight change	(lbs)
	TDELW:	Event time from beginning of stage	(sec)
	ALTC:	Impact altitude	(ft)
	BET:	Angle of solid propellant engine	(deg)
*	KA:	Targeting sequence number for parameter A	(-)
	A:	Guidance parameter A	(-)
*	KB:	Targeting sequence number for parameter B	(-)
	B:	Guidance parameter B	(-)
*	KE:	Terminal condition sequence number for energy	(-)
**	E:	Terminal condition energy	(ft^2/sec^2)
*	KH:	Terminal condition sequence number for any momentum	(-)
**	H:	Terminal condition angular momentum	(ft^2/sec)
	TLQB:	Starting time for liquid burn	(sec)
	ANS:	Solid propellant nozzle area	(ft)
*	KL:	Terminal condition altitude sequence number	(-)
	ALORB:	Terminal condition altitude	(ft)
*	KV:	Terminal condition velocity sequence number	(-)
	VORB:	Terminal condition velocity sequence number	(ft/sec)
*	KG:	Terminal condition flight path angle sequence number	(-)
	GORB:	Terminal condition flight path angle	(deg)
*	KLAT:	Terminal condition latitude sequence number	(-)
	TLAT:	Terminal condition latitude	(deg)
*	KLON:	Terminal condition longitude sequence number	(-)

TALA:	Terminal condition longitude	(deg)
WTSOL:	Total solid propellant	(lbs)
ISP:	Solid propellant specific impulse	(sec)
*	SOLN: Number of solid propellant engines	(-)

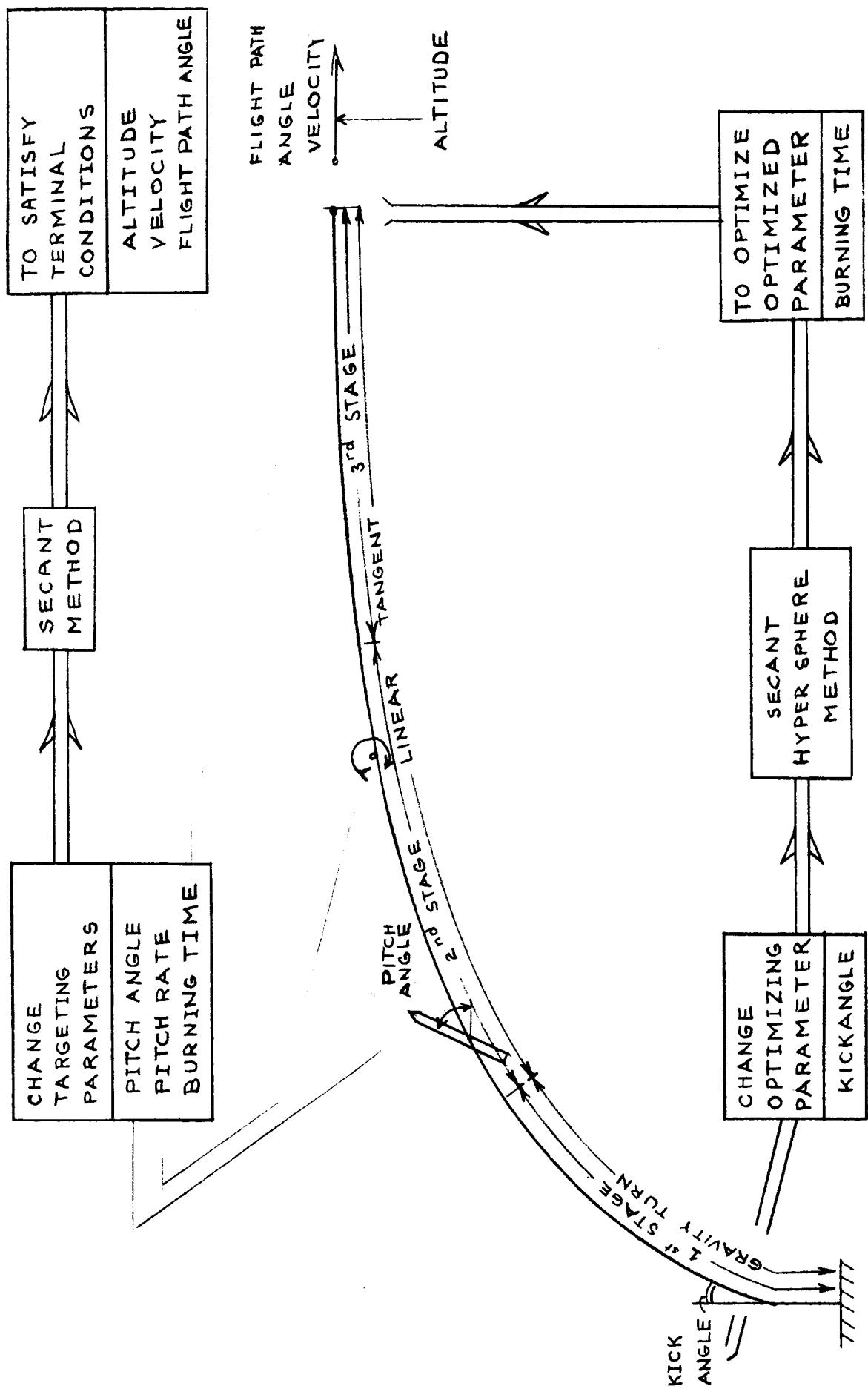


FIGURE 1

TABLE 2

SAMPLE LAUNCH TRAJECTORY OPTIMIZING TIME WITH KICK ANGLE
 1.4076 F16 2003520 72 28 230 096551
 4 -0.08
 CONST 02
 KICK 03
 SECT 04
 SEG2 10
 ACC 11
 1 3
 2 5
 10 1 •001
 150 -•006
 185 -•072
 1 •05
 350000 280000 4250000 7250000 140000 10 4 111 1 10 11 08
 2116.2 5005 500 800
 5 800 00000 1000000 8000 10
 2500 00000 1000000 250 1 1 50 11 12
 1 •42 -•0005
 00000 2000 90000
 1 •42 -•0005
 25000 450 220000 200000 400003 150 1 2 50 1 17
 1 •42 -•0005
 1 600000? 3
 \$INPUT
 NUMP=0,
 NUMT=0,
 SEND

TEST CASE FOR MEMO

DATE 270268

SAMPLE LAUNCH TRAJECTORY OPTIMIZING TIME WITH KICK ANGLE

```

.1408+17 20903520,00-0    72.00    28.00    280.00-0    99655.00 1
-.00     -.00     -.00     -.00     -.00 4    -.08      2.00
1       3       1       -0       -0       3
10.000   1.000   .001
150.000  -.096   -.000   -.000   -.000   -.000
185.000  -.072   -.000   -.000   -.000   -.000
1       .050000
1       3500000.00  28000.00-0  4250000.00-0  7250000.00  14000.00-0
2116.20  500.00 5    800.00   -.00   -.00-0   10.00   -.00 1-0-0 1-0 10
-.00     -.00-0   -.00-0   -.00   -.00-0   4.00    1.00 1 1-0 1-0 10
-.00     -.00 5    800.00   -.00   -.00-0   -.00    -.00 1-0-0 1-0 10
-.00     2500.00-0  900000.01-0 1000000.00   -.00-0   250.00  1.00 -0-0-0 1-0 50
-.00     -.00-0   -.00   -.00   8000.00  10.00   -.00 1-0-0 2
1       .400000 2   -.0005000-0-.00000000  -.00   -.00000000  -.0000  -.00 1-0-0 2 2-0 20
1       990000.00  2000.00-0   -.00-0   900000.01   -.00-0   -.00 1.00 -0-0 2 2-0 20
1       .400000 2   -.0005000-0-.00000000  -.00   -.00000000  -.0000  -.00 1-0-0 2 2-0 50
1       25000.00   450.00-0   220000.00-0  200000.00   4000.00 3   150.00  1.00 -0-0-0 2-0 50
1       .400000 2   -.0005000-0-.00000000  -.00   -.00000000  -.0000  -.00 3
1       608000.00 2   -.00 3   -.00-0   -.00-0   -.00   -.0000  -.0000  -.0000  -.0000
$VARIO
GMU   =   .14076000+17,
RADIUS =   .20903520+08,
KAZ   =   ,
AZI   =   .72000000+02,
ALATI =   .28000000+02,
ALAMDI =   .28000000+03,
KP    =   ,
PAYLD =   .99655000+05,
NTITLE =   1,
VZERO =   -.00000000+00,
GAZERO =   -.00000000+00,
ALZERO =   -.00000000+00,
RAZERO =   -.00000000+00,
TIZERO =   -.00000000+00,
KK    =   4,
AKICK =   -.79999998-01,
DELTk =   .20000000+01,
PLANET =   3,
ATMOS =   1,
CL    =   .00000000+00,
NUMP =   ,
NUMT =   ,
$END

SECTION 1
NTARG =           3      M      =           5      NTT      =           -0      NPNCf  □      -n
NOPTI =           3
EPS  =   .10000000+02
EPS  =   .10000000+01
EPS  =   .99999999-03
$OPTIO
EX   =   .15000000+03,
G    =   .18500000+03,
MX   =           1,
EP   =   .49999999-01,
C    =   -.95999998-01,   -.00000000+00,   -.00000000+00,   -.00000000+00,
```

TABLE 3

TEST CASE FOR MEMO

DATE 270268

```

D      = -.00000000+00,
D      = -.71999999-01,   -.00000000+00,   -.00000000+00,   -.00000000+00,
SEND

SEGMENT 1 SECTION 1

WDW   = .35000000+06    WDOT   = .28000000+05    KPR    =           -0    PROP   = .42500000+07
KTH   =           -0     TH     = .72500000+07    PL     = .14000000+05    KT     =           -0
TIMOP = -.00000000    DELT   = .10000000+01    NG     =           1     NSW    =           -0
NFLAG =           -0     NY     =           -0     JP     =           10    PN0Z   = .21162000+04
AN0Z  = .50000000+03    AFRO   = .80000000+03    FISP   = .25892857+03    DELW   = -.00000000
TDELW = .10000000+02    ALTC   = -.00000000    KA     =           0     A      = .00000000
KB    =           0     B      = .00000000    KE     =           0     E      = .00000000
KH    =           0     H      = .00000000    KL     =           0     ALORH = .00000000
KV    =           0     VORB   = .00000000    KG     =           0     GORB  = .00000000
KLAT  =           0     TLAT   = .00000000    KLON   =           0     TALA  = .00000000
EOT   = .00000000    EOTF   = .00000000    WD     = .00000000    TD    = .00000000

SEGMENT 2 SECTION 1

WDW   = -.00000000    WDOT   = -.00000000    KPR    =           -0    PROP   = -.00000000
KTH   =           -0     TH     = -.00000000    PL     = -.00000000    KT     =           -0
TIMOP = .40000000+01    DELT   = .10000000+01    NG     =           1     NSW    =           -0
NFLAG =           -0     NY     =           -0     JP     =           10    PN0Z   = -.00000000
AN0Z  = -.00000000    AFRO   = .80000000+03    FISP   = .00000000    DELW   = -.00000000
TDELW = -.00000000    ALTC   = -.00000000    KA     =           0     A      = .00000000
KB    =           0     B      = .00000000    KE     =           0     E      = .00000000
KH    =           0     H      = .00000000    KL     =           0     ALORH = .00000000
KV    =           0     VORB   = .00000000    KG     =           0     GORB  = .00000000
KLAT  =           0     TLAT   = .00000000    KLON   =           0     TALA  = .00000000
EOT   = .00000000    EOTF   = .00000000    WD     = .00000000    TD    = .00000000

SEGMENT 3 SECTION 1

WDW   = -.00000000    WDOT   = .25000000+04    KPR    =           -0    PROP   = .90000001+06
KTH   =           -0     TH     = .10000000+07    PL     = -.00000000    KT     =           -0
TIMOP = .25000000+03    DELT   = .10000000+01    NG     =           -0     NSW    =           -0
NFLAG =           -0     NY     =           -0     JP     =           50    PN0Z   = -.00000000
AN0Z  = -.00000000    AFRO   = -.00000000    FISP   = .40000000+03    DELW   = .80000000+04
TDELW = .10000000+02    ALTC   = -.00000000    KA     =           1     A      = .40000000-00
KB    =           2     B      = -.49999999-03    KE     =           -0     E      = -.00000000
KH    =           -0     H      = -.00000000    KL     =           0     ALORH = .00000000
KV    =           0     VORB   = .00000000    KG     =           0     GORB  = .00000000
KLAT  =           0     TLAT   = .00000000    KLON   =           0     TALA  = .00000000
EOT   = .00000000    EOTF   = .00000000    WD     = .00000000    TD    = .00000000

SEGMENT 4 SECTION 1

WDW   = .99000000+05    WDOT   = .20000000+04    KPR    =           -0    PROP   = -.00000000
KTH   =           -0     TH     = .90000001+06    PL     = -.00000000    KT     =           -0
TIMOP = -.00000000    DELT   = .10000000+01    NG     =           -0     NSW    =           -0
NFLAG =           2     NY     =           -0     JP     =           20    PN0Z   = .00000000
AN0Z  = .00000000    AFRO   = .00000000    FISP   = .45000000+03    DELW   = .00000000
TDELW = .00000000    ALTC   = .00000000    KA     =           1     A      = .40000000-00
KB    =           2     B      = -.49999999-03    KE     =           -0     E      = -.00000000
KH    =           -0     H      = -.00000000    KL     =           0     ALORH = .00000000
KV    =           0     VORB   = .00000000    KG     =           0     GORB  = .00000000

```

TABLE 4

TEST CASE FOR MEMO

DATE 270268

KLAT =	0	TLAT =	.00000000	KLON =	0	TALA =	.00000000
EOT =	.00000000	EOTF =	.00000000	WD =	.00000000	TD =	.00000000
SEGMENT 5 SECTION 1							
WDW =	.25000000+05	WDOT =	.45000000+03	KPR =	-0	PROP =	.22000000+06
KTH =	-0	TH =	.20000000+06	PL =	.40000000+04	KT =	3
TIMOP =	.15000000+03	DELT =	.10000000+01	NG =	-0	NSW =	-0
NFLAG =	-0	NY =	-0	JP =	50	PNOZ =	.00000000
AN0Z =	.00000000	AFRO =	.00000000	FISP =	.44444444+03	DFLW =	.00000000
TDELW =	.00000000	ALTC =	.00000000	KA =	1	A =	.40000000-00
KB =	2	B =	-.49999999-03	KE =	-0	E =	-.00000000
KH =	-0	II =	-.00000000	KL =	1	ALORR =	.60000000+06
KV =	2	VORR =	-.00000000	KG =	3	GORG =	-.00000000
KLAT =	-0	TLAT =	-.00000000	KLON =	-0	TALA =	-.00000000
EOT =	.00000000	EOTF =	.00000000	WD =	.00000000	TD =	.00000000

TABLE 5

TEST CASE FOR MEMO

DATE 270268

SAMPLE LAUNCH TRAJECTORY OPTIMIZING TIME WITH KICK ANGLE

GENERAL CONSTANTS

GRAVITATIONAL PARAMETERS .140760+17 FT3/SEC2
 CENTRAL BODY RADIUS 20903520.000 FT
 KICKING TIME INTERVAL 2.000 SEC
 KICK ANGLE -.080 DEG
 LAUNCH AZIMUTH 72.000 DEG
 LAUNCH LATITUDE 28.000 DEG
 LAUNCH LONGITUDE 280.000 DEG
 PAYLOAD 99655.001 LBS

INITIAL CONDITION

-0.000 FT/SFC
 -0.000 DFG
 -0.000 SFC
 -0.000 FT
 -0.000 NMILES

INPUT PARAMETERS SECTION 1 SEGMENT 1

BURNOUT WEIGHT	350000.00 LBS	NOZZLE PRESSURE	2116.20 LBS/FT2	EVENT TIME	10.00 SEC
BURNING RATE	28000.00 LBS/SEC	NOZZLE AREA	500.00 FT2	INTEGR. INTERVAL	1.00 SEC
PROPELLANT	4250000.00 LBS	FRONTAL AREA	800.00 FT2	WEIGHT CHANGE	-0.00 LBS
SPEC. IMPULSE	258.93 SEC	THRUST	7250000.00 LBS	INTER STAGE PAYLOAD	14000.00 LBS
A	.000000	B	.000000	DELTA V	10380.97 FT/SFC
STAGE GUIDANCE	GRAVITY TURN		STAGE BURNING TIME		151.79 SEC

COASTING PERIOD COASTING TIME 4.00 INTEGR. INTERVAL 1.00 SEC

INPUT PARAMETERS SECTION 1 SEGMENT 3

BURNOUT WEIGHT	-0.00 LBS	NOZZLE PRESSURE	-0.00 LBS/FT2	EVENT TIME	10.00 SEC
BURNING RATE	2500.00 LBS/SEC	NOZZLE AREA	-0.00 FT2	INTEGR. INTERVAL	1.00 SEC
PROPELLANT	6250000.00 LBS	FRONTAL AREA	-0.00 FT2	WEIGHT CHANGE	8000.00 LBS
SPEC. IMPULSE	400.00 SEC	THRUST	1000000.00 LBS	INTER STAGE PAYLOAD	-0.00 LBS
A	.400000	B	-.000500	DELTA V	8028.65 FT/SFC
STAGE GUIDANCE	LINEAR TANGENT		STAGE BURNING TIME		250.00 SEC

INPUT PARAMETERS SECTION 1 SEGMENT 4

BURNOUT WEIGHT	99000.00 LBS	NOZZLE PRESSURE	.00 LBS/FT2	EVENT TIME	.00 SEC
BURNING RATE	2000.00 LBS/SEC	NOZZLE AREA	.00 FT2	INTEGR. INTERVAL	1.00 SEC
PROPELLANT	2750000.00 LBS	FRONTAL AREA	.00 FT2	WEIGHT CHANGE	.00 LBS
SPEC. IMPULSE	450.00 SEC	THRUST	900000.01 LBS	INTER STAGE PAYLOAD	-.00 LBS
A	.400000	B	-.000500	DELTA V	6942.34 FT/SFC
STAGE GUIDANCE	LINEAR TANGENT		STAGE BURNING TIME		137.50 SEC

INPUT PARAMETERS SECTION 1 SEGMENT 5

BURNOUT WEIGHT	25000.00 LBS	NOZZLE PRESSURE	.00 LBS/FT2	EVENT TIME	.00 SEC
BURNING RATE	450.00 LBS/SEC	NOZZLE AREA	.00 FT2	INTEGR. INTERVAL	1.00 SEC
PROPELLANT	220000.00 LBS	FRONTAL AREA	.00 FT2	WEIGHT CHANGE	.00 LBS
SPEC. IMPULSE	444.44 SEC	THRUST	200000.00 LBS	INTER STAGE PAYLOAD	4000.00 LBS
A	.400000	B	-.000500	DELTA V	3080.73 FT/SFC
STAGE GUIDANCE	LINEAR TANGENT		STAGE BURNING TIME		150.00 SEC

VEHICLE WEIGHT HISTORY

SEC 1 SEG 1 INITIAL WEIGHT	5969655. LBS.	FINAL WIGHT	1719655. LBS.	
SEC 1 SEG 2 INITIAL WEIGHT	1355655. LBS.	FINAL WIGHT	1355655. LBS.	
SEC 1 SEG 3 INITIAL WEIGHT	1355655. LBS.	FINAL WIGHT	722655. LBS.	WGHT DECR. 8000. LB

TABLE 1

TEST CASE FOR MEMO

DATE 270268

SEC 1 SEG 4 INITIAL WEIGHT 722655. LBS. FINAL WEIGHT 447655. LBS.
SEC 1 SEG 5 INITIAL WEIGHT 348655. LBS. FINAL WEIGHT 281155. LBS. UNBRND PROP. 152500. LR

TARGETING PARAMETERS

SEC 1 SEG 3 A = .40000000-00
SEC 1 SEG 3 B = -.49999999-03
SEC 1 SEG 4 A = .40000000-00
SEC 1 SEG 4 B = -.49999999-03
SEC 1 SEG 5 A = .40000000-00
SEC 1 SEG 5 B = -.49999999-03
SEC 1 SEG 5 TIMOP = .15000000+03

OPTIMIZING PARAMETERS

AKICK = -.13962634-02

TERMINAL CONDITIONS

2 V = .25560208+05
3 GAMMA = -.00000000
1 ALT = .60800000+06

TEST CASE FOR MEMO

DATE 270268

TIME (SEC)	VELOCITY (FT/SEC)	GAMMA (DEG)	ALTITUDE (FT)	RANGE (N.MILES)	LAT (DEG)	LONG (DEG)	WEIGHT (LBS)	THRUST (LBS)	DRAG (LBS)	ALPHA (DEG)	α (LR/FT?)	HEATING (LR/FT)
693.29	25543.80	-2.178	247981.	1374.432	29.51	306.09	281155.	200000.	.0	9.655		
693.29	25327.04	-1.423	346652.	1364.079	29.52	305.90	281155.	200000.	.0	10.303		
693.29	25263.83	-1.156	371516.	1361.780	29.52	305.85	281155.	200000.	.0	10.974		
702.66	25482.14	-1.082	366867.	1398.218	29.48	306.55	276936.	200000.	.0	10.655		
725.70	25597.54	-.298	592439.	1454.617	29.40	307.62	266570.	200000.	.0	4.058		
ITERATION 1												

DETERMINANT OF A = .28898735+05
 MAXIMUM RELATIVE CORRECTION = .10365741-06

APPROXIMATE SOLUTION RESIDUAL VECTOR

.57444014-00	-.15560703+05
-.89263610-03	.17329346+02
.18241040+03	-.51961053-02

727.18	25579.12	.020	613079.	1458.984	29.40	307.71	265903.	200000.	.0	5.193
--------	----------	------	---------	----------	-------	--------	---------	---------	----	-------

ITERATION 2

DETERMINANT OF A = -.18328755+06
 MAXIMUM RELATIVE CORRECTION = .25597374-06

APPROXIMATE SOLUTION RESIDUAL VECTOR

.56584459-00	.50793750+04
-.83064022-03	-.10925293+01
.18389352+03	.34177748-03

726.82	25580.07	.004	608273.	1458.344	29.40	307.69	266064.	200000.	.0	5.314
--------	----------	------	---------	----------	-------	--------	---------	---------	----	-------

ITERATION 3

DETERMINANT OF A = -.17073481+06
 MAXIMUM RELATIVE CORRECTION = .42805227-06

APPROXIMATE SOLUTION RESIDUAL VECTOR

.56287121-00	.27335937+03
-.82269657-03	-.13452148-00
.18353656+03	.65654337-04

726.80	25580.21	.000	608003.	1458.260	29.40	307.69	266074.	200000.	.0	5.303
--------	----------	------	---------	----------	-------	--------	---------	---------	----	-------

TABLE 6

TEST CASE FOR MEMO

DATE 270268

TIME (SEC)	VELOCITY (FT/SEC)	GAMMA (DEG)	ALTITUDE (FT)	RANGE (N.MILES)	LAT (DEG)	LONG (DEG)	WEIGHT (LBS)	THRUST (LBS)	DRAG (LBS)	ALPHA (DEG)
ITERATION 4										
DETERMINANT OF A = .34044337+04										
MAXIMUM RELATIVE CORRECTION = .20766582-06										
APPROXIMATE SOLUTION RESIDUAL VECTOR										
.56294031-00 .31093750+01										
-.82331502-03 .41503906-02										
.18351357+03 .17550919-05										
ITERATION 4 .18351357+03										
-.13962634-02 .16666672-00 ,00000000										
726.80	25427.21	.127	673080.	1442.290	29.38	307.38	266074.	200000.	.0	5.175
726.80	25119.10	1.138	810324.	1425.367	29.40	307.06	266074.	200000.	.0	6.156
726.80	25010.66	1.594	853782.	1420.692	29.40	306.97	266074.	200000.	.0	7.350
738.27	25279.32	1.655	861954.	1463.769	29.34	307.79	260913.	200000.	.0	6.793
728.20	25584.30	.005	606901.	1457.883	29.35	307.68	265443.	200000.	.0	6.959
ITERATION 1										
DETERMINANT OF A = .93425565+05										
MAXIMUM RELATIVE CORRECTION □ .54876825-06										
APPROXIMATE SOLUTION RESIDUAL VECTOR										
.51714577-00 -.10985547+04										
-.69004257-03 .40959472+01										
.18491536+03 .93777864-04										
728.10	25580.24	-.000	608033.	1457.270	29.36	307.67	265490.	200000.	.0	6.886
ITERATION 2										
DETERMINANT OF A □ .23892201+06										
MAXIMUM RELATIVE CORRECTION = .73425869-07										
APPROXIMATE SOLUTION RESIDUAL VECTOR										
.51850125-00 .33281250+02										
-.69496000-03 .30029297-01										
.18481096+03 -.10410617-05										
728.09	25580.20	-.000	608001.	1457.275	29.36	307.67	265492.	200000.	.0	6.888

TABLE 9

TEST CASE FOR MEMO

DATE 270268

TIME (SEC)	VELOCITY (FT/SEC)	GAMMA (DEG)	ALTITUDE (FT)	RANGE (N.MILES)	LAT (DEG)	LONG (DEG)	WEIGHT (LBS)	THRUST (LBS)	DRAG (LBS)	ALPHA (DEG)
ITERATION 3										

DETERMINANT OF A = -.10537121+04
 MAXIMUM RELATIVE CORRECTION = .15999942-05

APPROXIMATE SOLUTION RESIDUAL VECTOR
 .51846674-00 .85156250-00
 -.69483922-03 -.90332031-02
 .18480733+03 -.52986024-08

ITERATION 3
 -.13543755-02 .18460733+03

728.09	25884.47	-.248	477765.	1489.050	29.39	308.28	265492.	200000.	.0	7.136
728.09	25591.28	.669	607480.	1473.039	29.41	307.98	265492.	200000.	.0	8.041
728.09	25496.01	1.046	644820.	1468.999	29.42	307.90	265492.	200000.	.0	9.051
739.64	25769.07	1.147	650481.	1513.736	29.35	308.75	260294.	200000.	.0	8.531
725.14	25573.26	-.036	601175.	1457.883	29.43	307.69	266822.	200000.	.0	3.819

ITERATION 1

DETERMINANT OF A = .74554373+05
 MAXIMUM RELATIVE CORRECTION = .29296900-06

APPROXIMATE SOLUTION RESIDUAL VECTOR
 .60566029-00 -.68245156+04
 -.04763190-03 -.69445801+01
 .18135081+03 -.62089144-03

726.02	25581.10	-.005	607444.	1460.405	29.43	307.74	266423.	200000.	.0	3.695
--------	----------	-------	---------	----------	-------	--------	---------	---------	----	-------

ITERATION 2

DETERMINANT OF A = -.11911584+06
 MAXIMUM RELATIVE CORRECTION = .39760323-07

APPROXIMATE SOLUTION RESIDUAL VECTOR
 .60885318-00 -.55602343+03
 -.95460245-03 .88989258-00
 .18273608+03 -.81391927-04

726.04	25580.26	.000	608004.	1460.427	29.43	307.74	266415.	200000.	.0	3.703
--------	----------	------	---------	----------	-------	--------	---------	---------	----	-------

TABLE 10

TEST CASE FOR MEMO

DATE 270268

TIME (SEC)	VELOCITY (FT/SEC)	GAMMA (DEG)	ALTITUDE (FT)	RANGE (N.MILES)	LAT (DEG)	LONG (DEG)	WEIGHT (LBS)	THRUST (LBS)	DRAG (LBS)	ALPHA (DEG)
ITERATION 3										
DETERMINANT OF A = -.10672687+05										
MAXIMUM RELATIVE CORRECTION = .40509496-07										
APPROXIMATE SOLUTION RESIDUAL VECTOR										
.60894394-00 .41640625+01										
-.95436139-03 .53710938-01										
.18275598+03 .17974518-05										
ITERATION 3										
-.14381513-02 .18275598+03										
.16666672-00 -.25589093-01										
726.04	25714.81	-.127	547312.	1474.430	29.45	308.01	266415.	200000.	.0	3.829
726.04	25379.88	.920	690593.	1456.010	29.47	307.65	266415.	200000.	.0	4.948
726.04	25253.80	1.434	739770.	1450.560	29.48	307.55	266415.	200000.	.0	6.355
737.46	25522.41	1.494	747174.	1494.144	29.42	308.38	261275.	200000.	.0	5.720
725.42	25576.37	-.016	605571.	1462.274	29.46	307.77	266693.	200000.	.0	2.237
ITERATION 1										
DETERMINANT OF A = .11084488+06										
MAXIMUM RELATIVE CORRECTION = .43591105-06										
APPROXIMATE SOLUTION RESIDUAL VECTOR										
.65187442-00 -.24294922+04										
-.10762975-02 -.38334960+01										
.18213695+03 -.28794225-03										
725.66	25578.92	-.007	606915.	1462.996	29.46	307.79	266588.	200000.	.0	2.227
ITERATION 2										
DETERMINANT OF A = -.96554774+04										
MAXIMUM RELATIVE CORRECTION = .20851191-06										
APPROXIMATE SOLUTION RESIDUAL VECTOR										
.65231036-00 -.10847422+04										
-.10766386-02 -.12844238+01										
.18237084+03 -.12224160-03										
725.81	25580.21	-.000	607997.	1463.467	29.46	307.80	266518.	200000.	.0	2.217

TABLE 11

TEST CASE FOR MEMO

DATE 270268

TIME (SEC)	VELOCITY (FT/SEC)	GAMMA (DEG)	ALTITUDE (FT)	RANGE (N.MILES)	LAT (DEG)	LONG (DEG)	WEIGHT (LBS)	THRUST (LBS)	DRAG (LBS)	ALPHA (DEG)
---------------	----------------------	----------------	------------------	--------------------	--------------	---------------	-----------------	-----------------	---------------	----------------

ITERATION 3

DETERMINANT OF A = .44935840+04
 MAXIMUM RELATIVE CORRECTION = .38901559-05

APPROXIMATE SOLUTION RESIDUAL VECTOR
 .65271221-00 -.26953125+01
 -.10771379-02 .41503906-02
 .18252663+03 -.22447966-06

ITERATION 3

.14767953-02 .18252663+03
 -.25589093-01 -.26503937-01

725.81	25581.50	-.001	607405.	1463.580	29.46	307.80	266518.	200000.	.0	2.218
725.81	25228.31	1.110	756841.	1444.062	29.49	307.43	266518.	200000.	.0	3.436
725.81	25088.77	1.691	811392.	1437.971	29.50	307.31	266518.	200000.	.0	5.032
737.22	25356.15	1.728	819972.	1481.044	29.44	308.13	261384.	200000.	.0	4.343
725.81	25580.16	-.000	607987.	1463.485	29.46	307.80	266519.	200000.	.0	2.203

ITERATION 1

DETERMINANT OF A = .13062126+06
 MAXIMUM RELATIVE CORRECTION = .27393134-06

APPROXIMATE SOLUTION RESIDUAL VECTOR
 .65314299-00 -.13429687+02
 -.10783476-02 -.43701172-01
 .18252353+03 -.20938250-05

725.81 25580.21 -.000 607998. 1463.494 29.46 307.80 266518. 200000. .0 2.203

ITERATION 2

DETERMINANT OF A = -.22970394+04
 MAXIMUM RELATIVE CORRECTION = .10739354-05

APPROXIMATE SOLUTION RESIDUAL VECTOR
 .65314372-00 -.16406250+01
 -.10783371-02 .24414063-02
 .18252660+03 -.24065229-08

.14771785-02 .18252660+03

TABLE 12

TEST CASE FOR MEMO

DATE 270268

SAMPLE LAUNCH TRAJECTORY OPTIMIZING TIME WITH KICK ANGLE

GENERAL CONSTANTS

GRAVITATIONAL PARAMETERS .140760+17 FT3/SEC2
 CENTRAL BODY RADIUS 20903520.000 FT
 KICKING TIME INTERVAL 2.000 SEC
 KICK ANGLE -.085 DEG
 LAUNCH AZIMUTH 72.000 DEG
 LAUNCH LATITUDE 28.000 DEG
 LAUNCH LONGITUDE 280.000 DEG
 PAYLOAD 99655.001 LBS

INITIAL CONDITION

VELOCITY -.000 FT/SFC
 FLIGHT PATH ANGLE -.000 DFG
 TIME -.000 SEC
 ALTITUDE -.000 FT
 RANGE -.000 NMII FS

INPUT PARAMETERS SECTION 1 SEGMENT 1

BURNOUT WEIGHT	350000.00 LBS	NOZZLE PRESSURE	2116.20 LBS/FT2	EVENT TIME	10.00 SEC
BURNING RATE	28000.00 LBS/SEC	NOZZLE AREA	.500.00 FT2	INTEGR. INTFRVAL	1.00 SEC
PROPELLANT	4250000.00 LBS	FRONTAL AREA	.800.00 FT2	WEIGHT CHANGE	-.00 LBS
SPEC. IMPULSE	258.93 SFC	THRUST	7250000.00 LBS	INTER STAGE PAYLOAD	14000.00 LBS
A	.000000	B	.000000	DELTA V	10380.97 FT/SFC
STAGE GUIDANCE	GRAVITY TURN		STAGE BURNING TIME		151.79 SEC

COASTING PERIOD COASTING TIME 4.00 INTEGR. INTERVAL 1.00 SEC

INPUT PARAMETERS SECTION 1 SEGMENT 3

BURNOUT WEIGHT	-.00 LBS	NOZZLE PRESSURE	-.00 LBS/FT2	EVENT TIME	10.00 SEC
BURNING RATE	2500.00 LBS/SEC	NOZZLE AREA	-.00 FT2	INTEGR. INTFRVAL	1.00 SEC
PROPELLANT	625000.00 LBS	FRONTAL AREA	-.00 FT2	WEIGHT CHANGE	8000.00 LBS
SPEC. IMPULSE	400.00 SEC	THRUST	1000000.00 LBS	INTER STAGE PAYLOAD	-.00 LBS
A	.653144	B	-.001078	DELTA V	8028.65 FT/SFC
STAGE GUIDANCE	LINEAR TANGENT		STAGE BURNING TIME		250.00 SEC

INPUT PARAMETERS SECTION 1 SEGMENT 4

BURNOUT WEIGHT	99000.00 LBS	NOZZLE PRESSURE	.00 LBS/FT2	EVENT TIME	.00 SEC
BURNING RATE	2000.00 LBS/SEC	NOZZLE AREA	.00 FT2	INTEGR. INTFRVAL	1.00 SEC
PROPELLANT	275000.00 LBS	FRONTAL AREA	.00 FT2	WEIGHT CHANGE	0.00 LBS
SPEC. IMPULSE	450.00 SEC	THRUST	900000.01 LBS	INTER STAGE PAYLOAD	-.00 LBS
A	.653144	B	-.001078	DELTA V	6942.34 FT/SFC
STAGE GUIDANCE	LINEAR TANGENT		STAGE BURNING TIME		137.50 SEC

INPUT PARAMETERS SECTION 1 SEGMENT 5

BURNOUT WEIGHT	25000.00 LBS	NOZZLE PRESSURE	.00 LBS/FT2	EVENT TIME	.00 SEC
BURNING RATE	450.00 LBS/SEC	NOZZLE AREA	.00 FT2	INTEGR. INTFRVAL	1.00 SEC
PROPELLANT	220000.00 LBS	FRONTAL AREA	.00 FT2	WEIGHT CHANGE	0.00 LBS
SPEC. IMPULSE	444.44 SEC	THRUST	200000.00 LBS	INTER STAGE PAYLOAD	4000.00 LBS
A	.653144	B	-.001078	DELTA V	3846.19 FT/SFC
STAGE GUIDANCE	LINEAR TANGENT		STAGE BURNING TIME		182.53 SEC

VEHICLE WEIGHT HISTORY

SEC 1 SEG 1 INITIAL WEIGHT	5969655. LBS.	FINAL WIGHT	1719655. LBS.	UNBRND PROP.	0. LB
SEC 1 SEG 2 INITIAL WEIGHT	1355655. LBS.	FINAL WIGHT	1355655. LBS.		
SEC 1 SEG 3 INITIAL WEIGHT	1355655. LBS.	FINAL WEIGHT	722655. LBS.	WGHT DECR.	8000. LB

TABLE 13

TEST CASE FOR MEMO

DATE 270268

SEC 1 SEG 4 INITIAL WEIGHT 722655. LBS. FINAL WEIGHT 447655. LBS.
SEC 1 SEG 5 INITIAL WEIGHT 348655. LBS. FINAL WEIGHT 266518. LBS. UNBRND PROP. 137863. LB

TABLE 14

TEST CASE FOR MEMO

DATE 270268

TIME (SEC)	VELOCITY (FT/SEC)	GAMMA (DEG)	ALTITUDE (FT)	RANGE (N.MILES)	LAT (DEG)	LONG (DEG)	WEIGHT (LBS)	THRUST (LBS)	DRAG (LBS)	ALPHA (DEG)	\dot{Q} (LR/FT2)	HEATING (LR/FT)
.00	.10	90.000	-0.	.000	28.00	280.00	5969655.	7250000.	.0	.000		
10.00	78.37	90.000	376.	.000	28.00	280.00	5689655.	7264156.	14392.9	.000	.7223+01	.1334+04
12.00	96.47	89.881	551.	.000	28.00	280.00	5633655.	7270739.	17531.3	-.085	.1089+02	.2924+04
20.00	177.86	89.159	1638.	.001	28.00	280.00	5409655.	7311009.	33090.9	.000	.3585+02	.2813+05
30.00	302.79	86.643	4016.	.015	28.00	280.00	5129655.	7394761.	52323.2	.000	.9677+02	.1850+06
40.00	459.92	82.050	7780.	.077	28.00	280.00	4849655.	7515345.	62786.8	.000	.1991+03	.7445+06
50.00	658.38	75.774	13225.	.253	28.00	280.00	4569655.	7666725.	93975.5	.000	.3436+03	.2259+07
60.00	904.95	68.561	20617.	.648	28.00	280.01	4289655.	7833799.	241553.1	.000	.5084+03	.5608+07
70.00	1202.11	61.112	30089.	1.385	28.01	280.02	4009655.	7994517.	408669.8	.000	.6418+03	.1172+08
80.00	1572.56	53.962	41700.	2.608	28.01	280.05	3729655.	8126853.	322104.4	.000	.6699+03	.2101+08
90.00	2033.94	47.494	55551.	4.482	28.02	280.08	3449655.	8214664.	232928.8	.000	.5777+03	.3227+08
100.00	2593.24	41.858	71698.	7.178	28.04	280.13	3169655.	8264851.	153161.0	.000	.4312+03	.4391+08
110.00	3258.96	37.053	90166.	10.878	28.06	280.20	2889655.	8289849.	85119.2	.000	.2020+03	.5414+08
120.00	4041.67	33.008	110988.	15.767	28.08	280.28	2609655.	8300998.	42269.0	.000	.1610+03	.6199+08
130.00	4956.93	29.628	134236.	22.045	28.11	280.40	2329655.	8305447.	18824.4	.000	.9346+02	.6725+08
140.00	6028.77	26.823	160068.	29.940	28.15	280.54	2049655.	8307131.	7994.8	.000	.4211+02	.7052+08
150.00	7294.75	24.516	168765.	39.719	28.20	280.71	1769655.	8307777.	3086.8	.000	.2136+02	.7254+08
151.79	7545.33	24.151	194224.	41.687	28.21	280.75	1719655.	8307839.	2535.0	.000	.1866+02	.7281+08
151.79	7545.33	24.151	194224.	41.687	28.21	280.75	1355655.	8307839.	2535.0	.000	.1866+02	.7281+08
155.79	7494.22	23.344	206337.	46.175	28.24	280.83	1355655.	8307839.	1563.0	.000	.1174+02	.7325+08
155.79	8705.20	19.946	206337.	46.175	28.24	280.83	1355655.	1000000.	.0	13.205		
165.79	8834.17	18.595	235267.	57.507	28.27	281.04	1330655.	1000000.	.0	14.120		
165.79	8834.17	18.595	235267.	57.507	28.27	281.04	1322655.	1000000.	.0	14.120		
200.00	9360.54	14.365	323076.	98.508	28.41	281.80	1237119.	1000000.	.0	16.828		
250.00	10347.37	9.303	422578.	165.461	28.61	283.05	1112119.	1000000.	.0	19.576		
300.00	11591.13	5.544	491958.	242.017	28.82	284.48	987119.	1000000.	.0	20.912		
350.00	13108.05	2.978	536455.	329.864	29.03	286.14	862119.	1000000.	.0	20.950		
400.00	14941.93	1.471	502405.	431.125	29.24	288.05	737119.	1000000.	.0	19.825		
405.79	15177.94	1.359	564554.	443.849	29.26	288.29	722655.	1000000.	.0	19.626		
405.79	15177.94	1.359	564554.	443.849	29.26	288.29	722655.	900000.	.0	19.626		
420.00	15717.60	1.052	569150.	475.937	29.32	288.90	694226.	900000.	.0	19.163		
440.00	16522.67	.726	574086.	523.219	29.40	289.80	654226.	900000.	.0	18.393		
450.00	17386.19	.520	577712.	573.166	29.47	290.75	614226.	900000.	.0	17.489		
480.00	18314.85	.429	580606.	625.971	29.54	291.76	574226.	900000.	.0	16.456		
500.00	19317.00	.446	583420.	681.857	29.61	292.83	534226.	900000.	.0	15.300		
520.00	20403.09	.570	586884.	741.073	29.66	293.96	494226.	900000.	.0	14.026		
540.00	21546.37	.795	591827.	803.905	29.71	295.16	454226.	900000.	.0	12.638		
543.29	21791.17	.841	592844.	814.620	29.72	295.37	447655.	900000.	.0	12.399		
543.29	21791.17	.841	592844.	814.620	29.72	295.37	348655.	200000.	.0	12.399		
550.00	21910.08	.765	594899.	836.646	29.73	295.79	345634.	200000.	.0	12.081		
560.00	22842.71	.311	605052.	104.693	29.78	299.01	323134.	200000.	.0	9.567		
650.00	23861.05	.048	608360.	1180.491	29.73	302.39	300634.	200000.	.0	6.807		
700.00	24970.05	-.030	608214.	1364.780	29.59	305.91	278134.	200000.	.0	3.823		
725.81	25580.21	-.000	607998.	1463.494	29.46	307.80	266518.	200000.	.0	2.203		

MAXIMUM Q = 684.7208 LB/FT2 AT 76.00 SEC

DRAG LOSSES = .15211727+03 FT/SEC

TABLE 15

TEST CASE FOR MEMO

DATE 270268

OPTIMIZATION HISTORY

SECTION 1

LOWER LIMITS OF OPTIMIZED AND OPTIMIZING

EX = .15000000+03 C = -.16755161-02,

UPPER LIMITS

G = .18499999+03 D = -.12566371-02,

SOLUTIONS FOR

	TIMOP	AKICK
0	.18351357+03	-.13962634-02
0	.18480733+03	-.13543755-02
0	.18275598+03	-.14381513-02
1	.18252663+03	-.14767953-02
2	.18252660+03	-.14771785-02

TABLE 16

<u>PLANET NAME</u>	<u>PLANET IDENTIFIER</u>	<u>EQUATORIAL RADIUS (FT)</u>	<u>GRAVITATIONAL CONSTANT (FT³/SEC²)</u>	<u>ROTATIONAL SPEED (RAD/SEC)</u>
Mercury	1	7,939,536	7.7 x 10 ¹⁴	.82596 x 10 ⁻⁶
Venus	2	19,684,800	1.1472 x 10 ¹⁶	.36342 x 10 ⁻⁶
Earth	3	20,925,467	1.40766 x 10 ¹⁶	.72884 x 10 ⁻⁴
Mars	4	11,187,528	1.516 x 10 ¹⁵	.70846 x 10 ⁻⁴
Jupiter	5	234,249,120	4.4747 x 10 ¹⁸	.16719 x 10 ⁻³
Saturn	6	198,160,320	2.044 x 10 ¹⁷	.16303 x 10 ⁻³
Uranus	7	77,098,800	2.044 x 10 ¹⁷	.11040 x 10 ⁻³
Neptune	8	73,161,840	2.4 x 10 ¹⁷	.110404 x 10 ⁻³
Pluto	9	22,965,600	1.1 x 10 ¹⁶	

TABLE 1: Planetary Constants

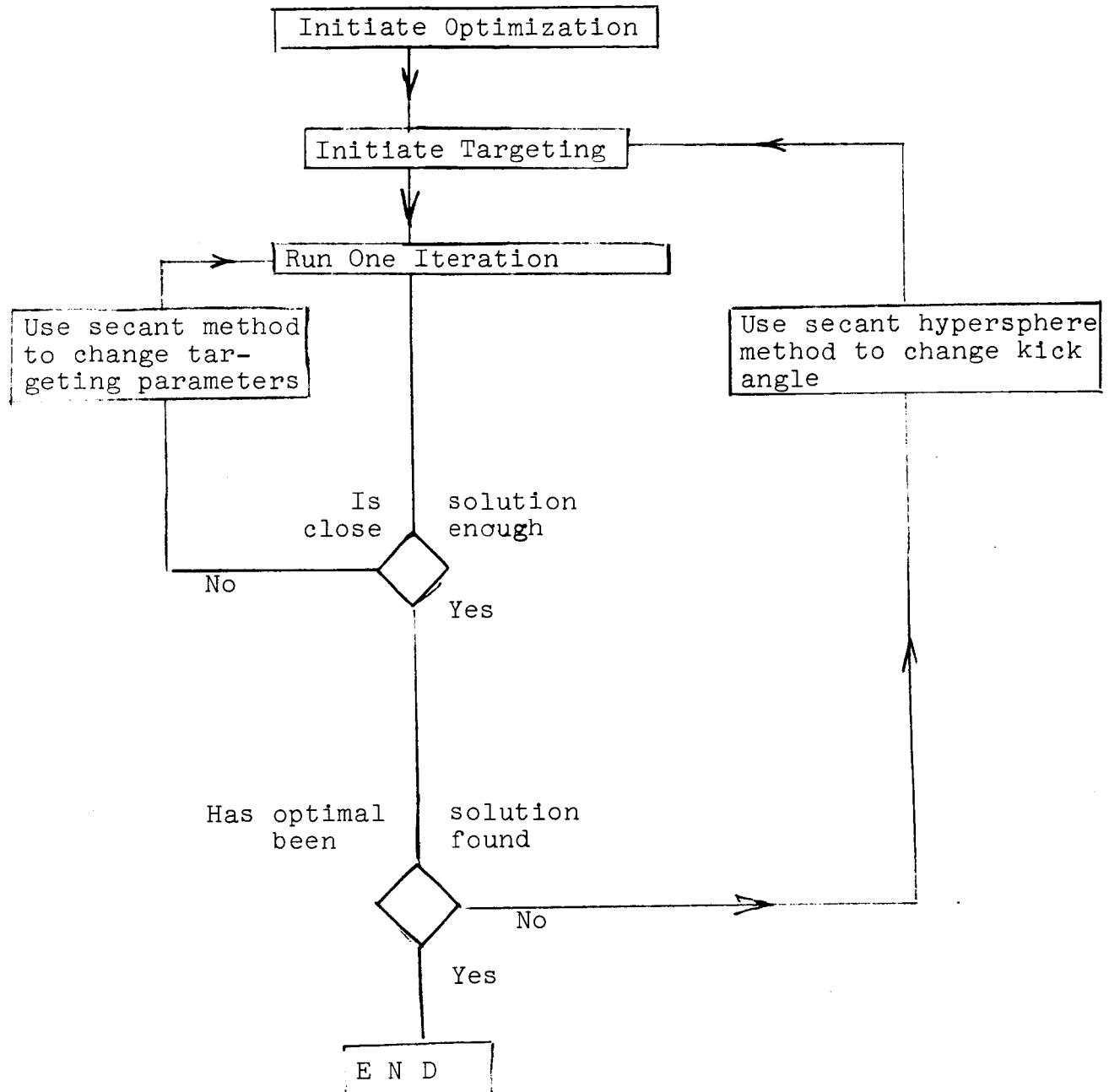


Figure 2